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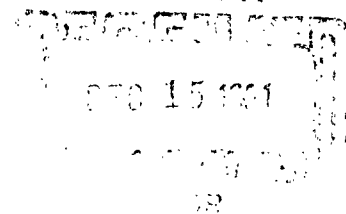
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THE FABRICATION BY PROJECTION WELDING
TECHNIQUES OF FINE WIRE BRIDGES FOR
ELECTRO - EXPLOSIVE DEVICES

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UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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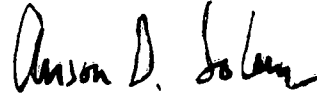
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THE FABRICATION BY PROJECTION WELDING TECHNIQUES
OF FINE WIRE BRIDGES FOR ELECTRO-EXPLOSIVE DEVICES

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ABSTRACT: An improved method for attaching bridgewires to the leads of electro-explosive initiator assemblies has been developed. Nickel tabs, to which has been swaged the bridge-wire, are projection welded to the contact pins. A discussion of the technique, optimum conditions for welding the nickel tab to several nickel alloys, and an analysis of the weld are presented. Several welded bridgewire assemblies functioned satisfactorily after subjection to standard environmental tests.

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This report presents information concerning a method of attaching fine bridgewires to initiator assemblies of electro-explosive devices. This work was carried out in the Explosion Dynamics Division of the Explosions Research Department, Naval Ordnance Laboratory, White Oak, Maryland in connection with Weptask RUME-3-E-016/2121/F008/10-004--Underwater Initiating Units. The results of this investigation are intended primarily for the information and use of the Naval Ordnance Laboratory, but should be of interest to others working with electro-explosive devices.

The author wishes to acknowledge the work by Mr. John Grimsley and Mr. William Grenier for the metallurgical analyses conducted on the weld samples.

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Captain, USN
Commander


C. J. ARONSON
By direction

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THE FABRICATION BY PROJECTION WELDING TECHNIQUES
OF FINE WIRE BRIDGES FOR ELECTRO-EXPLOSIVE DEVICES

INTRODUCTION

1. The most widely used method for attaching wire bridges to contact pins in electro-explosive device manufacture is that of soft soldering. Although this technique has been highly developed, it still has its disadvantages. These include, to mention a few:

- a. Lack of bridge resistance uniformity.
- b. Low solder joint strength.
- c. Melting of the solder at relatively low temperatures.
- d. Dissolution of the wire in the solder at the joint.

A technique for attaching fine wire bridges to contact pins which would eliminate some, or all, of these disadvantages would therefore be of interest.

2. Earlier work by the Sylvania Electric Products Company, Inc. (1) under contract to the Naval Ordnance Laboratory, indicated that the swaging of tungsten wire into nickel tabs and the spot welding of these tabs to initiator plugs to form resistance wire bridges was feasible. Their method was as follows:

a. Combinations of nickel alloy pins and "A" nickel strips were chosen for the welding materials.

b. A thin strip of "A" nickel was punched to a desired geometry to form the bridgewire tabs. The geometry chosen facilitated the removal of excess material after the welding operation.

c. The nickel strip was then etched to form a closely controlled gap which determined the length of the bridge.

(1) Terminal Report on Initiator Primer. Product Development Laboratory, Sylvania Electric Products Inc. Contract NOrd 14225, November 28, 1955 (Confidential).

d. With the aid of a jig, fine tungsten wire was cold swaged across the gap in the nickel strip. This operation formed the mechanical and electrical bond for the bridgewire.

e. Each tab was spot welded to its contact pin with several passes of the machine. No jig was used during this operation.

f. After the welding operation, the excess nickel strip was removed from the pins.

3. The welding technique was satisfactory but presented the following problems.

a. Alignment - All alignment was done by hand on individual plugs.

b. Electrodes - Electrodes required maintenance because of erosion.

c. Production efficiency - Spot welding operation required up to four strokes of the machine for a satisfactory weld area.

d. Weld - Additional strokes of the machine caused a non-uniform weld area which is not desirable for the best strength.

The basic technique looked promising for application to electro-explosive device manufacture. However, it was believed that the method could be improved upon by using a projection welding technique.

4. In projection welding, the current flow (and heating) during welding are localized by proper design of the parts to be joined. Some of the advantages of this method are: (2)

a. Increased output for each stroke of the machine since two welds can be made simultaneously.

b. Longer electrode life, since the pressure and current are being localized by the projection thereby reducing electrode wear.

c. Improved location of welds by means of a fixture.

In this particular case, the projection or embossment was placed on the thin strip of tab material where it was to be joined to

(2) "Resistance Welding Data Book", P. R. Mallory & Co., Inc. Indianapolis 6, Indiana, 4th Edition.

the lead pin as shown in Figure 1. The shape of the embossment (diameter and depth for the particular thickness of material worked with) is the most important mechanical parameter in controlling the welding. The method of bridgewire fabrication by the use of projection welding was found to be feasible. It is a method by which controlled bridgewire lengths may be obtained and is adaptable to production techniques used for the manufacture of electro-explosive devices.

TOOL AND ELECTRODE DESIGN

5. Since the geometry of the embossment was the most important factor in the strip construction, tools for forming the embossment were designed with close tolerances and good surfaces. Considered in the design of the embossing tools was the possibility of cold swaging the bridgewire into the strip simultaneously with forming the embossment. This was found to be possible and the tool designed to perform both the embossing and the swaging is shown in Figure 2.

6. The embossment in the projection welding process serves as the tip of the upper electrode and presents no real problem to the design of the actual electrode itself. Both the strip and the alloy electrical pins contain a high percentage of nickel. Therefore, for good compatibility with the high percentage nickel bearing material to be welded, a copper-chromium alloy (Mallory 3 - Class 2) was used as the electrode material. Since the embossment acts as the contour of the upper electrode the upper electrode tip itself was made flat with a contacting surface diameter larger than the base diameter of the embossment. The bottom electrode was made of the same material as the upper electrode with the exception that the bottom section of the electrode contained manganin (copper, manganese, nickel alloy) which was used as a current measuring shunt in the welding process. Manganin was used because it has a high specific resistance and a low temperature coefficient of resistivity. Thus, once the shunt is calibrated, it remains accurate with small changes in temperature.

MONITORING EQUIPMENT

7. For each weld made during the program a measurement was made of the current and the pressure pulse. The pressure measurement was made using a low pressure strain gage link designed specifically for the purpose. The link had attached four strain gages and was substituted for a section of the top electrode as shown in Figure 3. The welding machine had no facility for measuring pressure accurately; therefore, the pressure link proved to be a necessary modification of the equipment. The

gages mounted on the link were the Baldwin SR-4, Type C-14, positioned circumferentially along the periphery of the tension link so that the center line of each grid was 90° away from the load axis. Duco cement was used to bond the gages to the link. A special housing was fabricated to keep the gages from grounding electrically to the link and to facilitate assembly of cables to the gages. A four-conductor shielded cable was used to carry the signal from the link to a bridge amplifier*. The signal was used to trigger an oscilloscope and to monitor the pressure during the welding time.

8. The current was measured from the bottom electrode. The manganin shunt (a section of the bottom electrode, see Paragraph 6) was used. Both the current and pressure trace were recorded by a camera** mounted on an oscilloscope***.

DISCUSSION

9. Strip material of "A" nickel in several hardnesses was tried. The first strip used was "dead soft". This material was discarded because the punching operation caused burrs in the bridge slot and was difficult to align in the welding jig. More strips were fabricated, strip annealed (under optimum conditions) in hydrogen at 900°C, and cold rolled to give the desired hardness. To facilitate the removal of excess nickel following the welding operation, a scribe mark was placed on the strip prior to the punching operation. This is shown in the punched strips in Figure 4. Two designs of punched strip are shown in Figure 4. The original design did not break properly at the scribed mark at any of the various strip hardnesses. Therefore, the punch and die were redesigned to remove more material from the strip. The final strip design is as shown in Figure 4. This was the optimum design for the fabrication of the metal tabs used to hold the bridgewire. The strip was prepared for the swaging of the tungsten wire and the welding operation by dipping in a pickling solution which degreased the strip and removed any oxide coatings from it. The solution (recommended by the International Nickel Company for cleaning nickel) was composed of dilute nitric and sulfuric acids containing sodium chloride.

10. Prior to the swaging operation the fine tungsten wire was placed along the axis of the strip and held in place by small pieces of masking tape or small spots of lacquer. The strip

* Ellis Associates Model BA-1 or equivalent.

** Polaroid-Land Camera or equal.

*** Tektronix 545 or equal.

and wire were then placed on the swaging die with the wire between the strip and the die. This permitted the hard surface of the die to be used as an anvil when the punch was seated on the strip. The tungsten wire was cold swaged into the nickel strip with a force of 1200-1400 pounds (dead load) and the two projections were embossed simultaneously. The assembly of tungsten wire and nickel strip can be seen in Figure 5. In designing the projection, the size and shape must satisfy the following conditions: (3)

- a. It should be strong enough to stand the initial pressure before the current is applied, without yield or flattening.
- b. It must have sufficient mass to raise a spot in the sheet to welding temperature. If too small, it will collapse before the plain sheet is at welding temperature.
- c. It should collapse without splashing between the sheets.
- d. It should be easy to raise so that the punch and die should have a long life without attention.

The handling of the strips from the time of degreasing was done with thin rubber gloves to prevent contamination prior to welding. The swaging punch and die was also kept free of oils and foreign materials.

11. The welding apparatus required modification in order to make the projection weld and to facilitate the monitoring of the welding operation. The welding jigs were designed to hold the nickel strip and the initiator plug. The design of the strip jig was such that adjustments could be made in the position of the embossments with respect to the pins on the plug. In addition, the alignment pins on the jig facilitated quick removal of the strip. This allowed welding of each plug with controlled alignment which was not accomplished by the earlier method and is more suitable for production type welding.

12. The upper and lower electrode design included, among other considerations, the following:

- a. The electrodes must conduct welding current into the materials to be welded and also, simultaneously apply a substantial force to the area to be welded.
- b. During the welding operation, the electrodes must dissipate the heat, by conduction, rapidly away from the outer surface of the materials being welded.

(3) "Precision Welding of Small Parts by Spot and Projection Methods", by J. L. Miller, The Welding Industry, March 1940.

c. Since the upper electrode applies force and carries current to the area containing the bridgewire, the possibility exists for burning out the bridgewire.

d. The bottom electrode is to make contact with both pins of the plug simultaneously, so that current can be supplied equally to each.

A drawing of the upper and lower electrodes (Figure 6) shows the design used for the welding of the nickel strip to the plug. The upper and lower electrodes were made of Mallory 3 - Class 2 alloy which is a recommended material for welding nickel alloys. The upper electrode was adequate and required no maintenance. The lower electrode gave some problems with arcing between the electrode and spring loaded contact but a redesign of the springs solved the problem.

13. The nominal compositions and some of the physical properties of the materials to be welded are shown in Table 1. The welding program was planned to determine optimum conditions for welding combinations of nickel strip with nickel alloys. The pins of the initiator plug were made of the nickel alloys and the strip of "A" Nickel. The welding pressure and current were varied with the material combinations and the weld strength observed. The weld strength was determined by welding short pieces of the strip to the pins which were assembled into a pulling jig. This jig was placed in a Baldwin Southworth Universal Test Machine and the sample pulled in tension to destruction at the rate of 0.05 inch/min. The ultimate strength of the specimen was recorded and is shown with the weld condition in Tables 2, 3, 4, and 5. A brief explanation of the headings on the above tables is as follows:

a. Nickel strip hardness - The Vickers Hardness Test was made on the nickel strip following the cold rolling operation to insure an accurate hardness record.

b. Electrode Force - The actual pounds of force applied to the weld sample by the top electrode. This value is accurate to within one pound.

c. Stored Energy - The energy delivered to the weld sample was recorded from a watt-second meter attached to the welding machine.

d. Mean Tension Shear Strength - Determinations of tension shear strengths were made on a standard test machine, pulling the test specimen to destruction. The nickel strip, projection welded to the nickel alloy pins, was pulled at right angles across the welds. The ultimate strength of the specimen was

recorded when the weld material sheared out or when the strip was torn out. The tabulated values are the mean values of shear strength as calculated from a 10-shot sample. The standard deviation and coefficient of variation are self explanatory.

e. Failures - The failures are the number of weld samples of the 10-shot group which did not weld on one stroke of the machine and were not included in the tension-shear tests.

14. With respect to an analysis of the data to determine which alloy provided the best weld, several points are to be considered. The first item to be considered is what parameter is the most important to the consumer for the acceptance of the sample. The tabulations of mean tension-shear strength indicate all of the alloys chosen will weld to "A" nickel under various conditions of pressure and current. Of the four alloy pins, the iron-chrome-nickel (MIL-W-3068) and the Kovar gave the most uniform strengths for various welding conditions. The Kovar-to-nickel weld exhibited the highest average shear strength of 28.3 pounds with a coefficient of variation of 25.9 percent. This variation may appear to be large but the welds would still be acceptable. In considering optimum conditions for welding Kovar to nickel, the nickel strip hardness was VHN 230 and was welded to the Kovar with a force of 10 pounds. The energy delivered to the weld samples was 60 watt-seconds.

15. In examining the weld samples after the tension-shear test, further support was given to the data by observation of the nugget or area of the weld. Photomicrographs of the plugs, with the nickel strips pulled off during the shear strength, are shown in Figures 7 and 8. The largest and most uniform weld areas are seen with the Kovar and iron-chrome-nickel pins. Parts of the nickel strip are remaining in the Kovar to nickel weld. This combination of strip and alloy was the only one of the four to show this strength. This might be considered an optimum condition as far as the strength of the materials are concerned. This weld strength was found to be approximately 86% to 97% of the ultimate shear strength for the nickel strip at R_B 98 hardness.

16. During the welding operation, several welds failed by shorting out across the bridge gap or by blowing metal out from between the parts being welded. Metal expulsion may be caused by:

- a. Welding too near an edge.
- b. Welding of dirty material.
- c. Welding with too little pressure or too much current.

Typical oscillograms of a satisfactory weld and a weld which had metal expulsion are shown in Figure 9. This method of monitoring was a satisfactory method of determining whether or not a weld sample had received the desired amount of energy. Examples of metal expulsion are shown in Figure 10.

17. In welding dissimilar metals, the greatest difficulty can be expected in a combination which, when mixed in the weld nugget, forms an alloy of undesirable characteristics. Any procedure which will minimize the mixing of the two base materials in the nugget would be helpful. High welding currents with short welding times tend to do this. An unconventional braze type weld where the nugget is entirely contained within one material with a braze type adherence might be useful.

18. A metallurgical analysis of a typical weld was performed. The weld sample consisted of two Inconel pins welded to a nickel strip. A 0.0002-inch tungsten wire bridged the two pins. The specimen selected for metallographic examination was considered to have been fabricated under nearly optimum conditions for this combination of materials. The sample was mounted, polished, and etched by standard metallographic procedures. To study the size and shape of the welds, small increments of metal were removed from the specimen by grinding, repolishing, and etching. The specimen was examined after removal of each increment. Representative photomicrographs were made at selected intervals. The equiaxial microstructure at the top of the photomicrographs, as shown in Figure 11, is the Inconel and the cold worked microstructure on the bottom is the nickel strip. There was no apparent bonding between the Inconel and nickel strip in the area between the two fusion zones. The Inconel is observed to have recrystallized, but there was no apparent change in the microstructure of the nickel strip.

19. Microhardness tests were conducted across the welds to determine the extent of the heat affected zones. The microhardness test results are presented in Figure 12. The projection welding procedure produced very small fusion zones in the weld samples. The bonding in those areas where fusion occurred is considered to be good. No cracks or other defects were observed in the fusion zone, and satisfactory penetration was obtained.

20. Following the punching of the nickel strip, the cold swaging of the tungsten wire, and the projection welding of the tabs, the removal of the excess nickel strip is the final operation. The scribed area shown in Figure 1 facilitates the removal of the strip. A typical example of the bridgewire and welded tabs is shown in Figure 13. This type of plug assembly was used throughout the program and was also used in the environmental testing.

21. The welds were subjected to various environmental tests to determine their suitability for use in electro-explosive devices. The welded assemblies were tested in the actuator shown in Figure 14. The actuators were subjected to the following environmental tests:

- a. Transportation Vibration (MIL-STD-353)
- b. Aircraft Vibration (TN-1441-VIA)
- c. Forty-foot Drop Test (MIL-STD-302)
- d. Hi-G Air-Gun Test.

Since the electrical continuity was the most important parameter for investigation in these tests, a check of resistance of the bridge was made before and after the tests. The result following the Hi-G Air-Gun Tests (5,250 g. axial shock) indicated no open bridges. Resistance checks following the other tests also indicated no open bridges.

CONCLUSIONS

22. By using the projection welding method with nickel strip containing embossments:

- a. Tabs containing a cold swaged tungsten wire can be welded to the pins of electro-explosive devices to form a satisfactory bridge.
- b. The most suitable welds were obtained with the "A" nickel and Kovar pins at 10 pounds welding pressure and 60 watt-seconds of energy delivered to the weld.
- c. The welds obtained had the strength of the parent material.
- d. Welded bridgewire assemblies of a representative electro-explosive device passed all rough handling tests as evidenced by intact bridgewires.

Table 1.
The Physical Properties of Metals
Selected for Welding

Property	Materials to be Welded				
	Grade A Nickel	Iron- Chrome - Nickel	Monel	Inconel	Kovar
Electrical Resistivity (Microhm cm.) (ohm/cir.mil.ft.)	9.5 57	70 max. --	48.2 290	98.2 590	45 270
Thermal Conductivity (cal/sq.cm/sec/°C/cm)	0.145	--	0.062	0.036	0.040
Melting Point (°C)	1435-1445	--	1300-1350	1395-1425	1450 approx.
Yield Strength, (K psi)	70-105	162	90-130	90-125	50.5
Tensile Strength (K psi) Hardness	90-115 * R _B 90	216	100-140 R _B 98	125-150 * R _C 25	89.7
Nominal Composition (%)	99.4 Ni	8.5-14.0 Ni 0.5 Cu 17 Cr 66 Fe approx.	68 Ni 30 Cu 1 Mn 1 Fe	79 Ni 13 Cu 7 Fe	29 Ni 17 Cu 0.2 Mn 53 Fe approx.

* R_B, R_C - Rockwell Hardness Scales

Table 2

Tension-Shear Strengths for "A" Nickel Strips Welded to Monel (QQ-N-281A)
Pins Under Various Welding Conditions

Nickel Strip Hardness (VHN)**	Electrode Force (pounds)	Stored Energy (watt-sec)	Mean Tension Shear Strength * (pounds)	Standard Deviation (pounds)	Coefficient of Variation (%)	Failures***
230	5	60	13.2	5.3	40.3	1
	5	75	16.8	8.7	51.8	1
200	5	60	9.4	5.8	61.5	0
	5	75	23.6	6.4	27.2	0
196	5	60	18.5	4.0	21.8	0
	5	75	16.5	5.2	31.3	0
230	10	60	6.4	3.2	49.5	4
	10	75	10.1	5.8	57.2	1
200	10	60	7.1	5.1	72.8	2
	10	75	16.7	9.2	55.3	1
196	10	60	5.1	3.1	62.0	0
	10	75	9.9	2.2	22.4	0

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* Sample Size 10 ea.

** Vickers Hardness Scale

*** Failure to weld

Table 3

Tension-Shear Strengths for "A" Nickel Strips Welded to Inconel (QQ-W-390A)
Pins Under Various Welding Conditions

Nickel Strip Hardness (VHN)**	Electrode Force (pounds)	Stored Energy (watt-sec)	Mean Tension Shear Strength * (pounds)	Standard Deviation (pounds)	Coefficient of Variation (%)	Failures***
230	10	60	10.1	1.3	12.4	4
	10	70	11.1	2.4	21.6	0
	10	75	9.3	4.7	50.4	0
200	10	60	7.5	1.6	20.4	3
	10	70	8.9	4.4	48.8	2
	10	75	11.2	5.6	50.3	1
196	10	60	7.4	3.0	40.3	3
	10	70	5.0	3.1	62.8	2
	10	75	6.6	5.8	87.8	1
230	5	75	17.5	8.7	49.8	0
200	5	60	9.8	5.0	51.2	0
	5	75	21.3	7.7	36.0	0
196	5	60	16.6	3.4	20.3	2
	5	75	19.2	4.7	24.2	1

* Sample Size 10 ea.

** Vickers Hardness Scale

*** Failure to weld

Table 4

Tension-Shear Strengths for "A" Nickel Strips Welded to Iron-Chrome-Nickel
(MIL-W-3068) Pins Under Various Welding Conditions

Nickel Strip Hardness (VHN)**	Electrode Force (pounds)	Stored Energy (watt-sec)	Mean Tension Shear Strength * (pounds)	Standard Deviation (pounds)	Coefficient of Variation (%)	Failures***
230	5	60	14.8	7.5	50.7	1
	5	75	23.8	6.2	25.9	1
200	5	60	22.2	4.8	21.6	1
	5	75	25.9	5.3	20.3	2
196	5	60	20.4	4.2	20.3	0
	5	75	18.8	7.6	40.4	0
230	10	60	7.8	4.4	56.5	1
	10	75	13.4	5.2	38.5	0
200	10	60	15.1	6.4	42.1	0
	10	75	14.7	6.1	41.6	0
196	10	60	10.3	6.1	59.2	0
	10	75	16.4	7.3	44.3	0

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* Sample Size 10 ea.

** Vickers Hardness Scale

*** Failure to weld

Table 5

Tension-Shear Strengths for "A" Nickel Strips Welded to Kovar* Pins
Under Various Welding Conditions

Nickel Strip Hardness (VHN)**	Electrode Force	Stored Energy (watt-sec)	Mean Tension Shear Strength***	Standard Deviation (pounds)	Coefficient of Variation (%)	Failures****
230	10	40	15.2	15.1	99.0	2
	10	60	28.3	7.3	25.9	1
200	10	40	20.4	5.8	28.4	0
	10	60	24.4	4.2	17.1	1
196	10	40	16.9	3.7	22.1	0
	10	60	23.9	3.9	16.5	0
230	15	40	14.5	3.8	26.2	2
	15	60	19.1	7.9	41.4	2
200	15	40	17.4	11.0	63.2	1
	15	60	14.9	9.2	61.2	1
196	15	75	22.0	8.3	37.9	1
200	20	60	10.9	7.5	68.4	1
	20	80	14.9	4.9	32.7	0
196	20	60	13.4	3.7	27.4	2
	20	80	16.2	7.7	47.2	1

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*Kovar: Nickel/Cobalt/Manganese/Iron (29/17/0.2/53.8)

**Weld Sample Size 10 ea.

***Vickers Hardness Scale

****Failure to weld

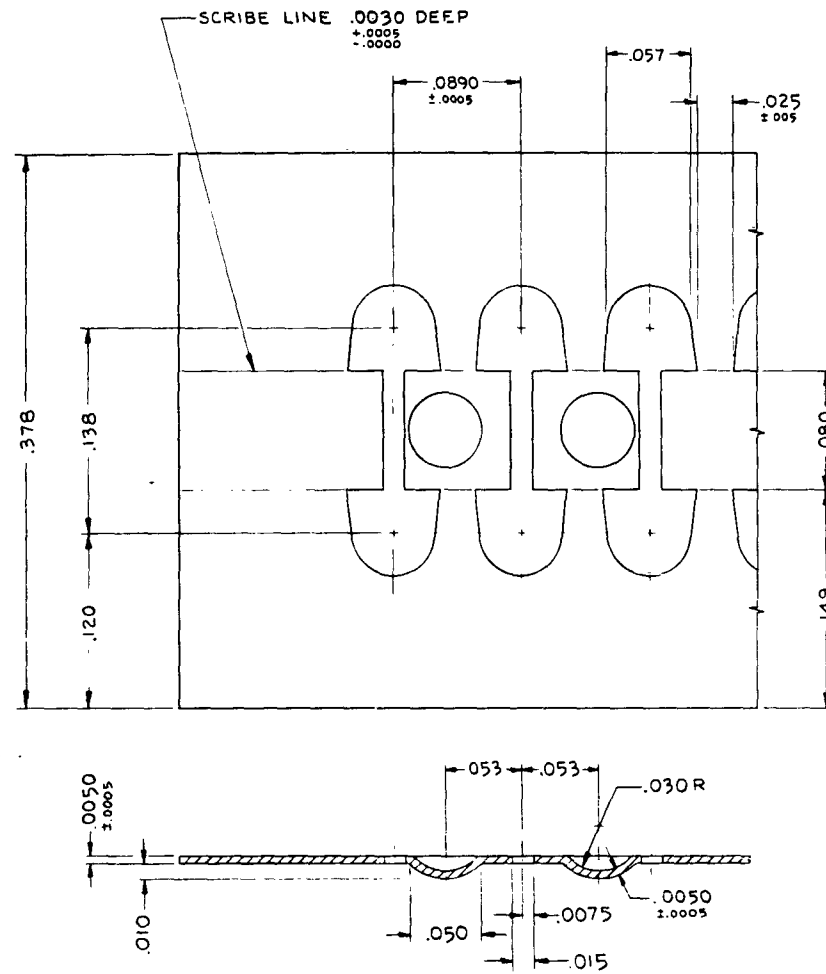


FIG.1 THE NICKEL STRIP WITH EMBOSSEMENTS (FINAL DESIGN)

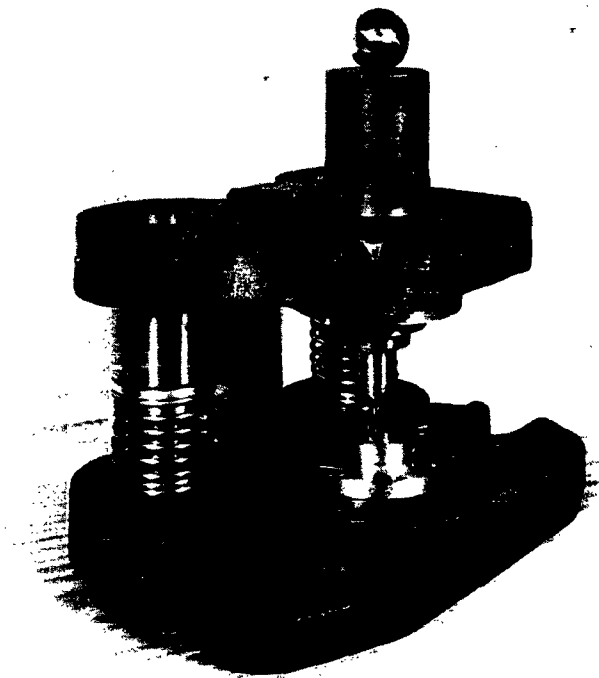


FIG.2 THE PUNCH AND DIE ASSEMBLY FOR SWAGING
THE TUNGSTEN WIRE INTO THE NICKEL STRIP.

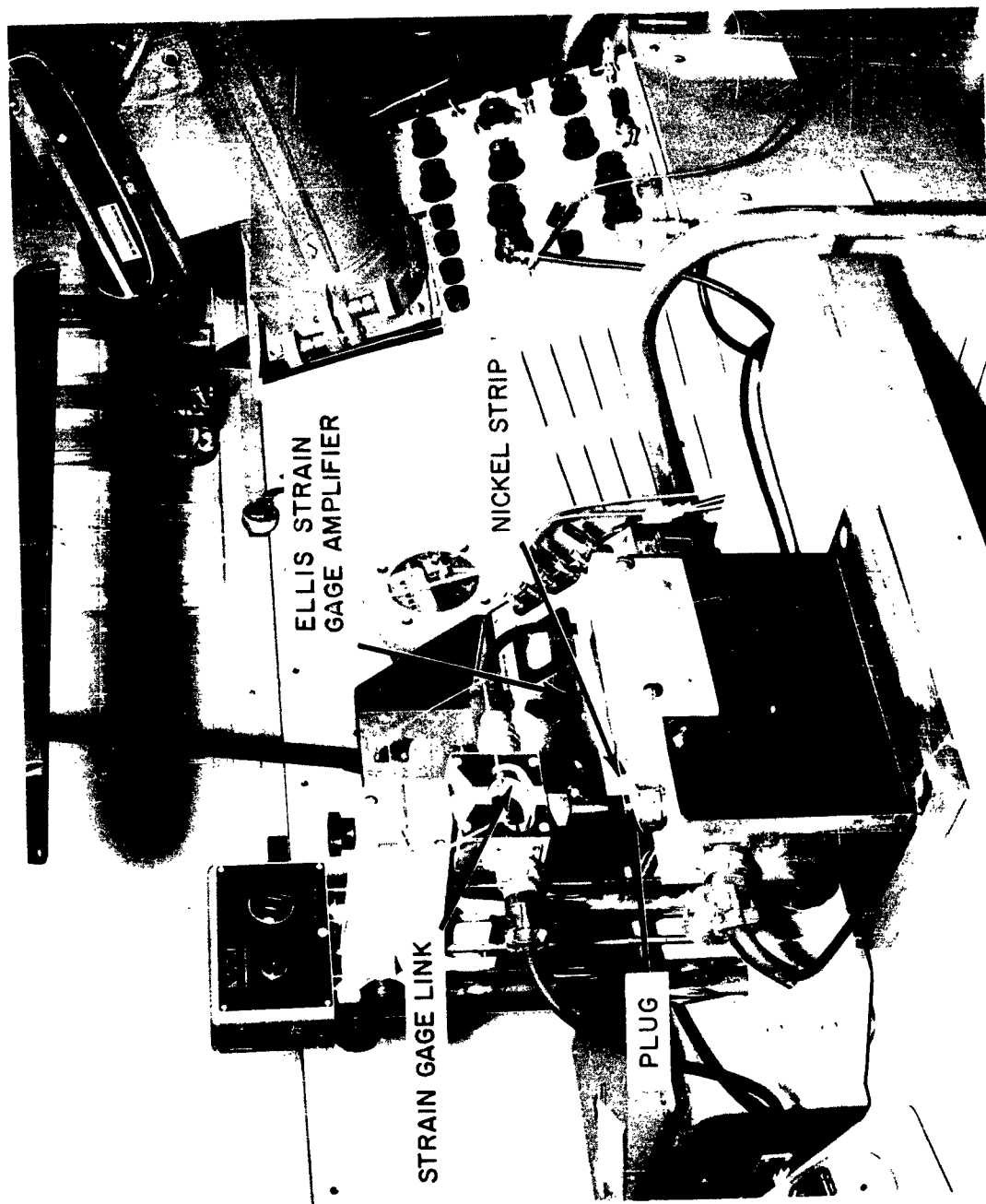


FIG. 3 THE PROJECTION WELDING MACHINE AND MONITORING EQUIPMENT

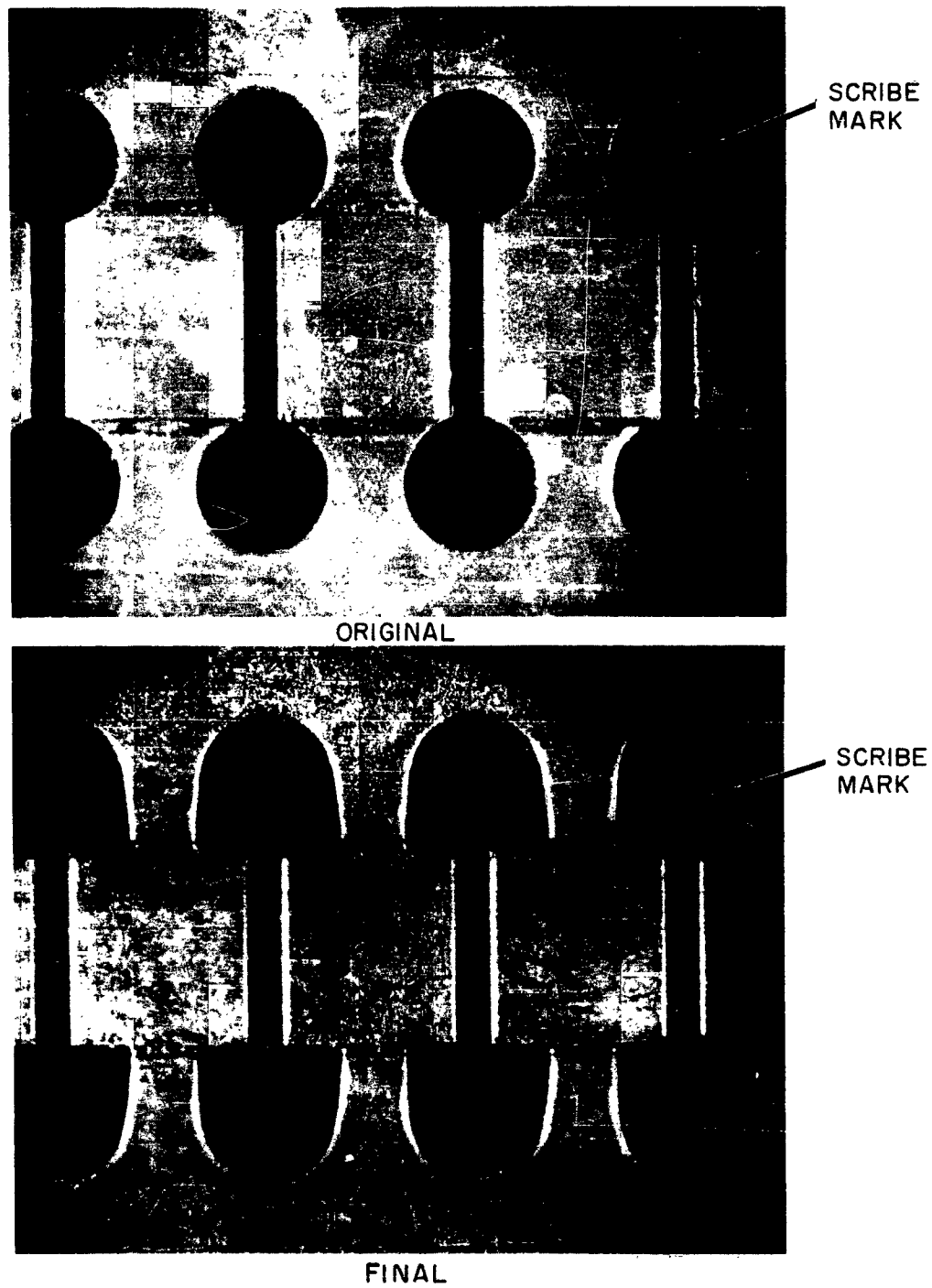


FIG.4 THE ORIGINAL AND FINAL DESIGN OF THE NICKEL STRIP

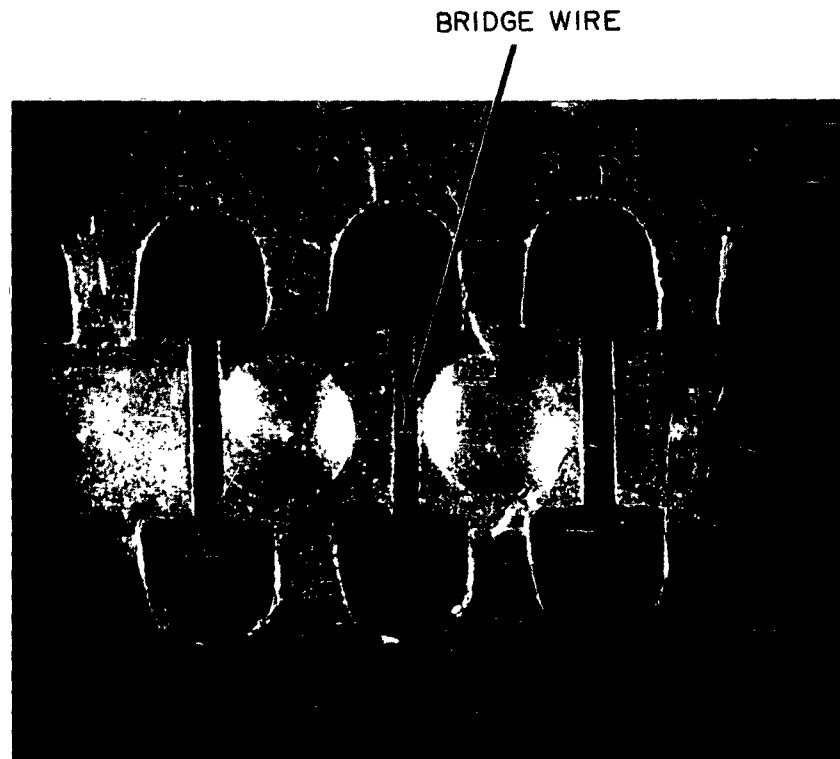


FIG.5 THE FINAL ASSEMBLY OF THE TUNGSTEN WIRE AND NICKEL STRIP.

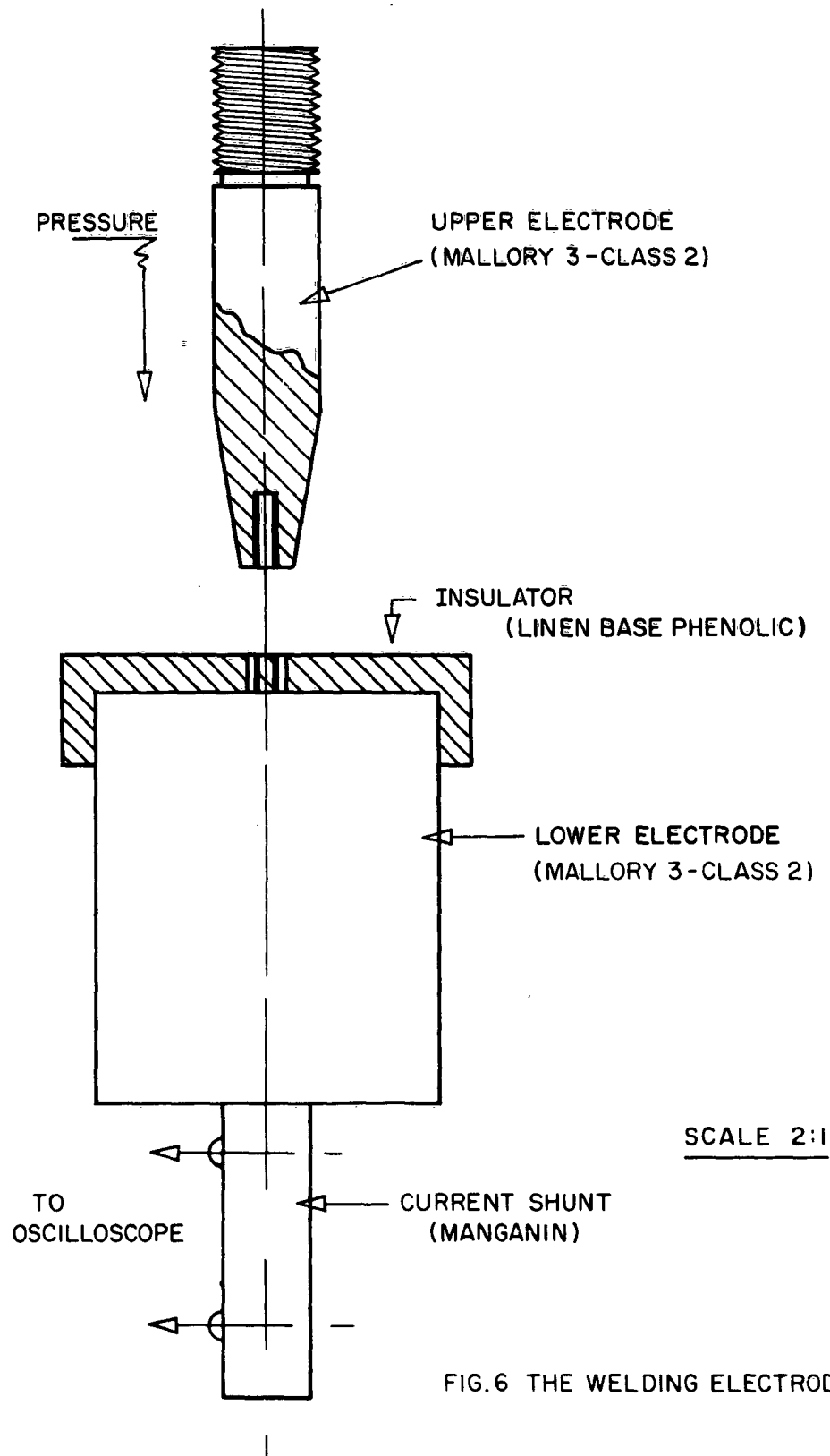
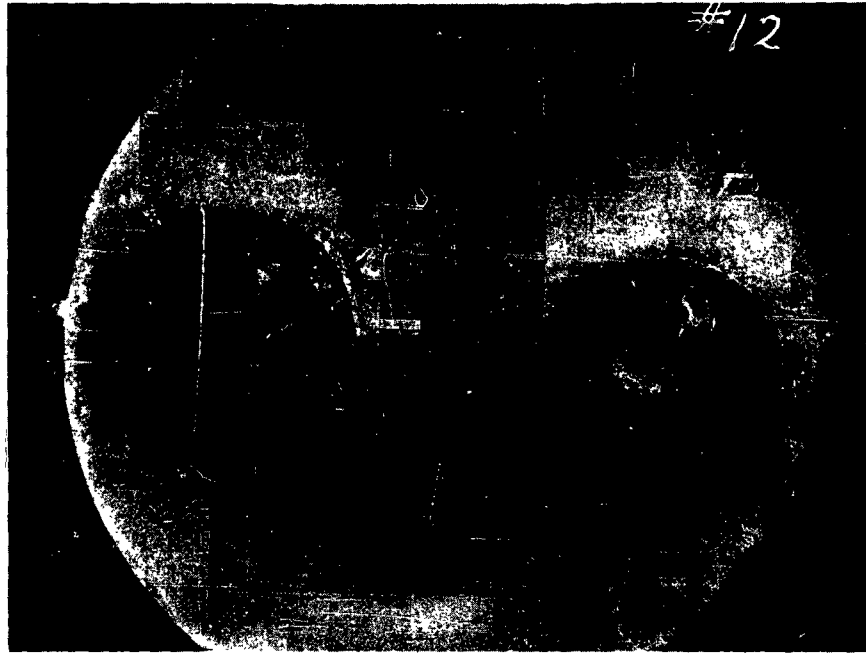


FIG.6 THE WELDING ELECTRODE ARRANGEMENT



QQ-W-390A



QQ-N-281A

FIG.7 THE NICKEL ALLOY PINS (QQ-W-390A AND QQ-N-281A) WITH WELD NUGGET CAVITY FOLLOWING TENSION-SHEAR TEST.

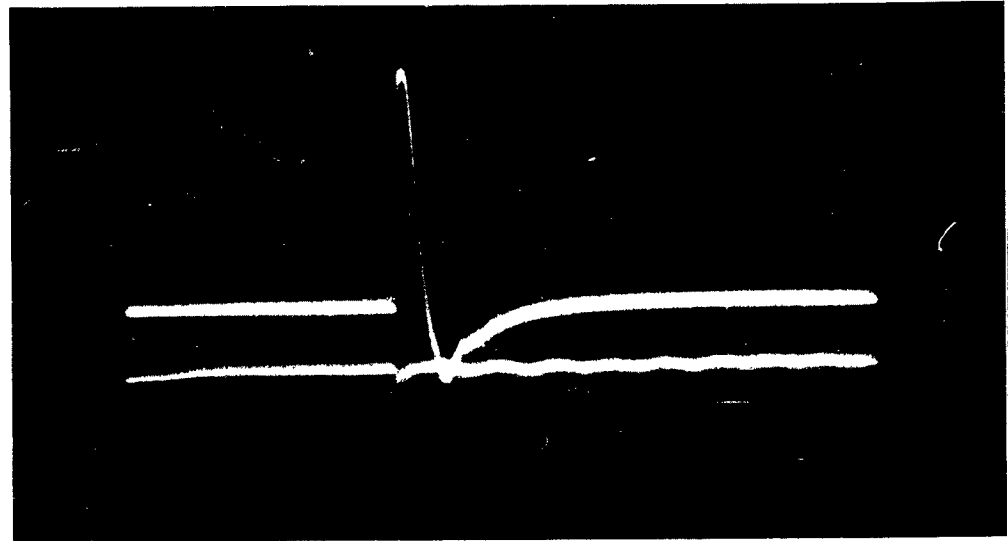


MIL-W-3068

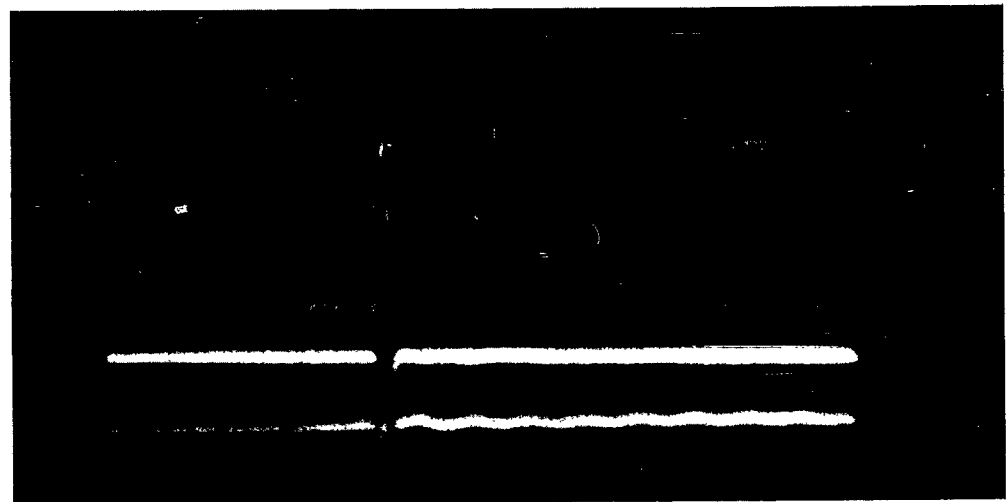


KOVAR

FIG.8 THE NICKEL ALLOY PINS (MIL-W-3068 AND KOVAR) WITH WELD NUGGET CAVITY FOLLOWING TENSION-SHEAR TEST.



TYPICAL WELD



METAL EXPULSION

VERTICAL SENSITIVITY: 0.2 V/CM. SWEEP TIME: 5 MS/CM

FIG.9 CURRENT AND PRESSURE TRACES SHOWING A TYPICAL WELD AND A WELD WITH METAL EXPULSION.

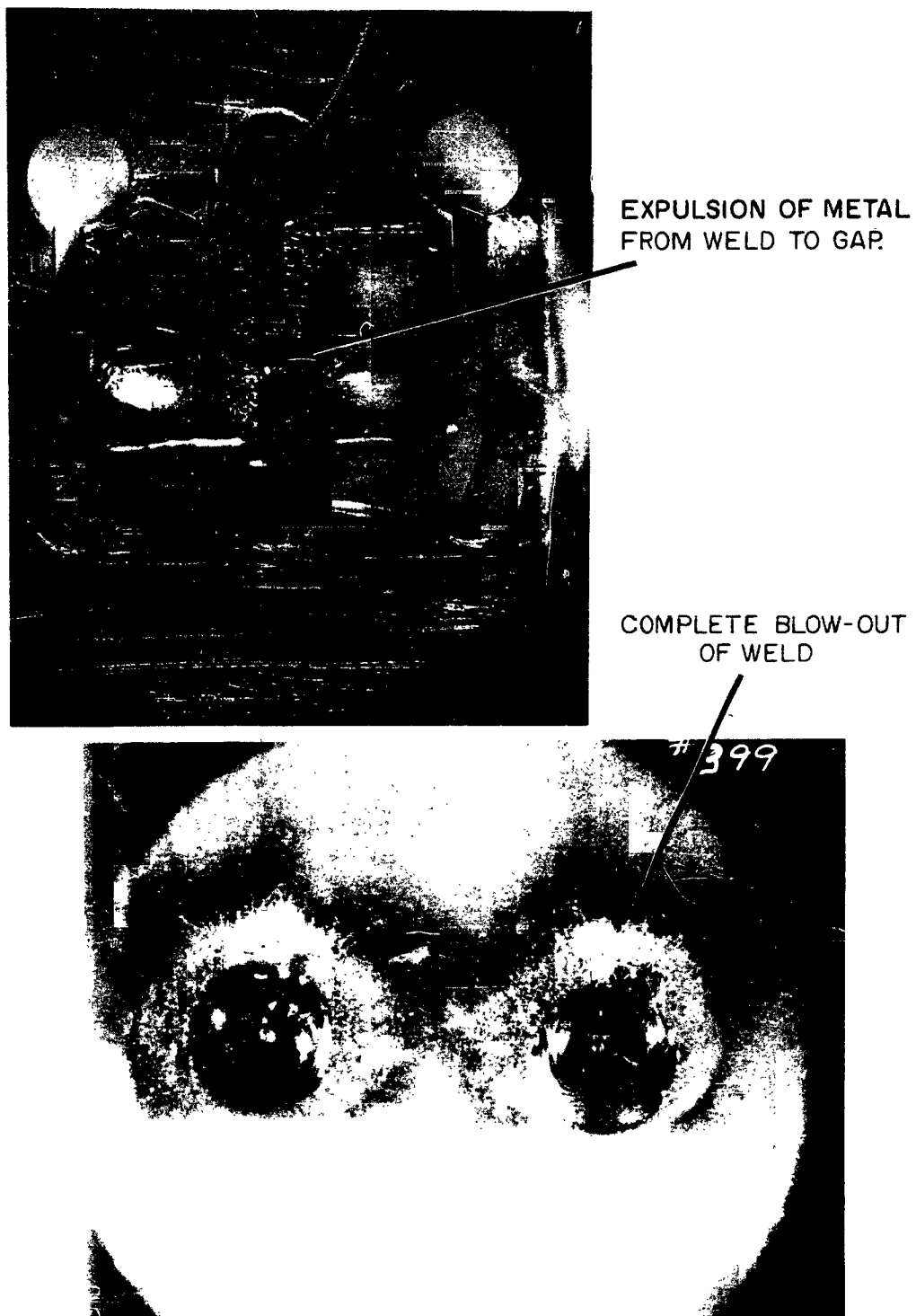
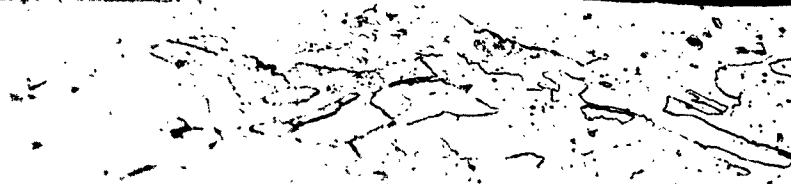


FIG.10 THE TYPICAL METAL EXPULSION FROM NICKEL STRIP AND NICKEL ALLOY PINS.



INCONEL



NICKEL

MAGNIFICATION 500X



INCONEL



NICKEL

MAGNIFICATION 250X

FIG. II PHOTOMICROGRAPHS SHOWING THE PIN WELD WHEN THE TWO FUSION ZONES WERE FIRST DETECTED; SPECIMEN ETCHED ELECTROLYTICALLY IN 5% H_2SO_4

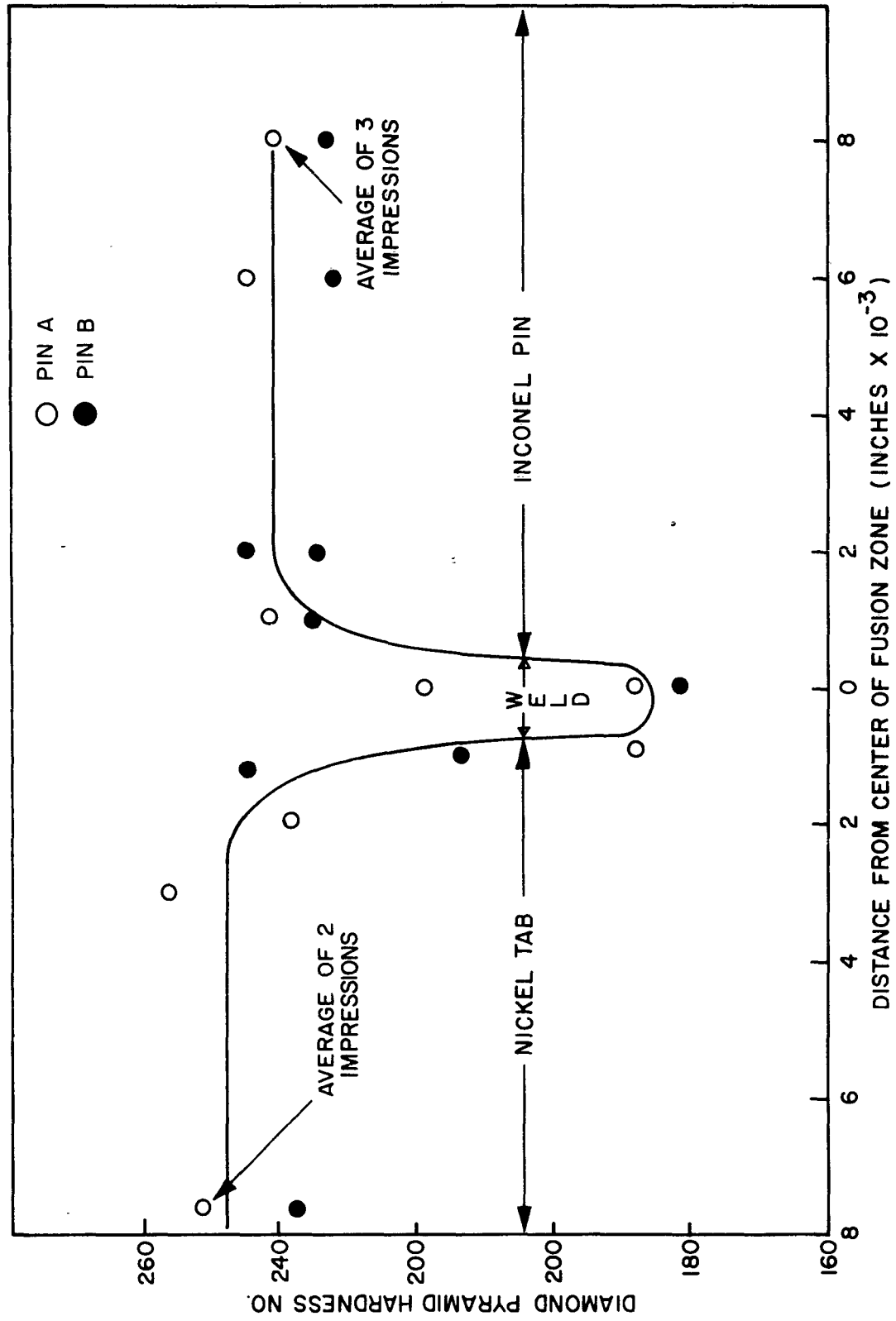


FIG. 12 THE MICROHARDNESS TRAVERSE ACROSS A WELD-ZONE

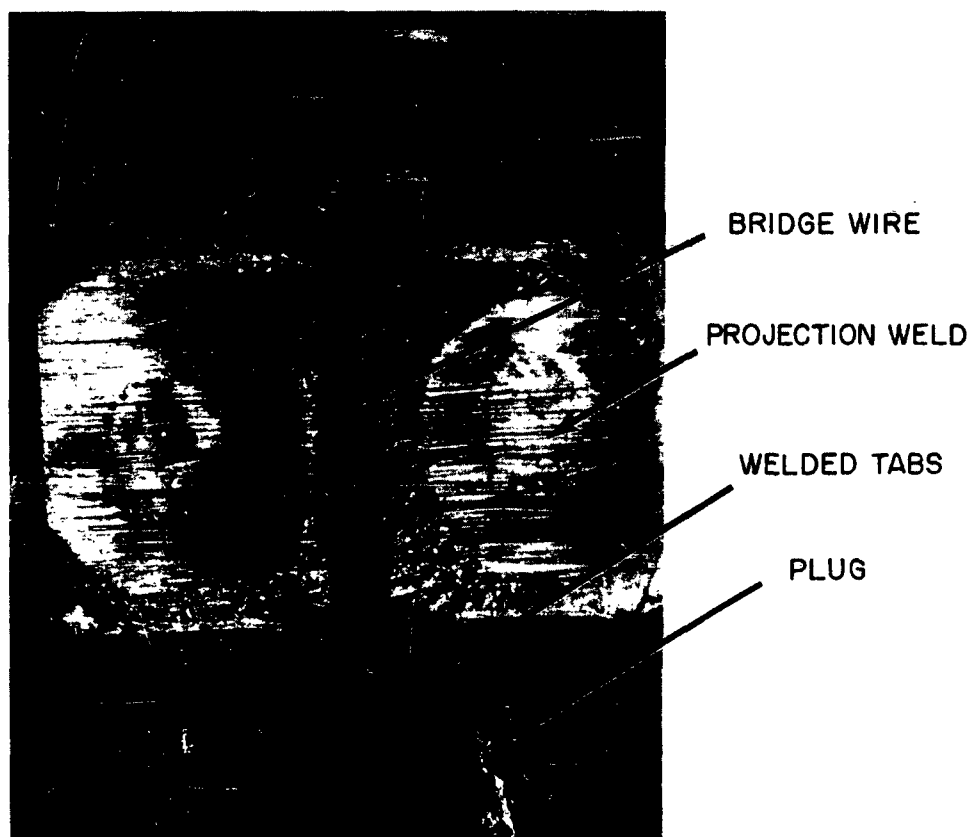


FIG. 13 THE NICKEL TABS WELDED IN PLACE WITH BRIDGE WIRE ATTACHED

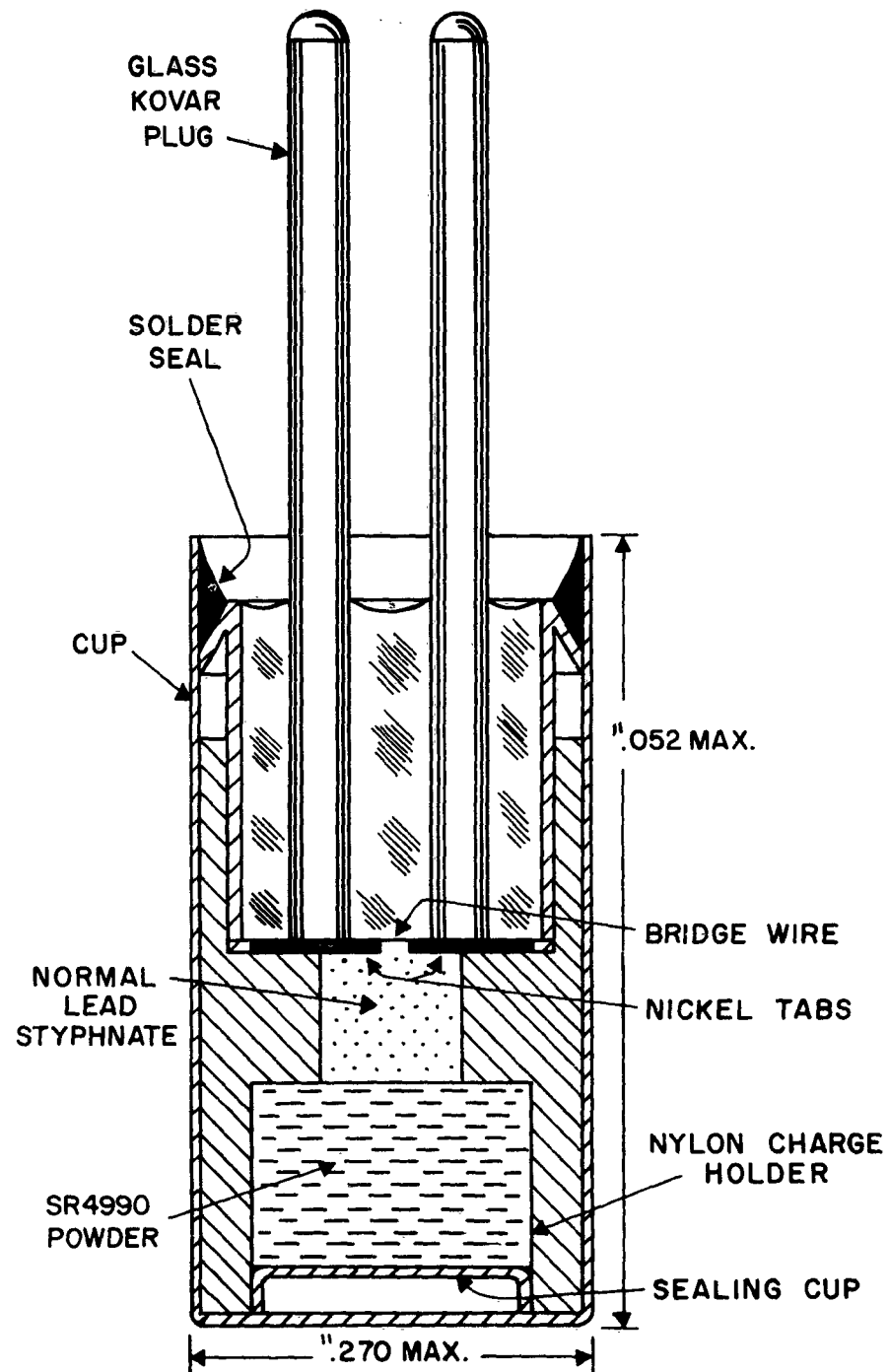


FIG. 14 THE EXPERIMENTAL ACTUATOR USED IN THE ENVIRONMENTAL TESTING.

<p>Naval Ordnance Laboratory, White Oak, Md. (NOL technical report 61-119) THE FABRICATION BY PROJECTION WELDING TECHNIQUES OF FINE WIRE BRIDGES FOR ELECTRO- EXPLOSIVE DEVICES (U), by E. Eugene Kilmer. 8 Sept. 1961. 28p. illus. Task RUME-3-E- 016/2121/FO08/10-004. UNCLASSIFIED</p> <p>An improved method for attaching bridge- wires to the leads of electro-explosive initiator assemblies has been developed. Nickel tabs, to which has been swaged the bridgewire, are projection welded to the contact pins. A discussion of the technique, optimum conditions for welding the nickel tab to several nickel alloys, and an analysis of the weld are presented. Several welded bridgewire assemblies functioned satisfactor- ily after subjection to standard environ- mental tests.</p> <p>Abstract card is unclassified</p>	<ol style="list-style-type: none"> 1. Electro- explosive devices 2. Wire, Bridge - Fabrication 3. Initiators, Electro- explosive I. Title II. Kilmer, E. Eugene III. Project
<p>Naval Ordnance Laboratory, White Oak, Md. (NOL technical report 61-119) THE FABRICATION BY PROJECTION WELDING TECHNIQUES OF FINE WIRE BRIDGES FOR ELECTRO- EXPLOSIVE DEVICES (U), by E. Eugene Kilmer. 8 Sept. 1961. 28p. illus. Task RUME-3-E- 016/2121/FO08/10-004. UNCLASSIFIED</p> <p>An improved method for attaching bridge- wires to the leads of electro-explosive initiator assemblies has been developed. Nickel tabs, to which has been swaged the bridgewire, are projection welded to the contact pins. A discussion of the technique, optimum conditions for welding the nickel tab to several nickel alloys, and an analysis of the weld are presented. Several welded bridgewire assemblies functioned satisfactor- ily after subjection to standard environ- mental tests.</p> <p>Abstract card is unclassified</p>	<ol style="list-style-type: none"> 1. Electro- explosive devices 2. Wire, Bridge - Fabrication 3. Initiators, Electro- explosive I. Title II. Kilmer, E. Eugene III. Project
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